Water Resources of North Dakota

Lake-Level Frequency Analysis for Devils Lake, North Dakota

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Two approaches were used to estimate future lake-level probabilities for Devils Lake. The first approach is based on an annual lake-volume model, and the second approach is based on a statistical water mass-balance model that generates seasonal lake volumes on the basis of seasonal precipitation, evaporation, and inflow. Autoregressive moving average models were used to model the annual mean lake volume and the difference between the annual maximum lake volume and the annual mean lake volume. Residuals from both models were determined to be uncorrelated with zero mean and constant variance. However, a nonlinear relation between the residuals of the two models was included in the final annual lake-volume model. Because of high autocorrelation in the annual lake levels of Devils Lake, the annual lake-volume model was verified using annual lake-level changes. The annual lake-volume model closely reproduced the statistics of the recorded lake-level changes for 1901-93 except for the skewness coefficient. However, the model output is less skewed than the data indicate

because of some unrealistically large lake-level declines. The statistical water mass-balance model requires as inputs seasonal precipitation, evaporation, and inflow data for Devils Lake. Analysis of annual precipitation, evaporation, and inflow data for 1950-93 revealed no significant trends or long-range dependence so the input time series were assumed to be stationary and short-range dependent. Normality transformations were used to approximately maintain the marginal probability distributions; and a multivariate, periodic autoregressive model was used to reproduce the correlation structure. Each of the coefficients in the model is significantly different from zero at the 5-percent significance level. Coefficients relating spring inflow from one year to spring and fall inflows from the previous year had the largest effect on the lake-level frequency analysis. Inclusion of parameter uncertainty in the model for generating precipitation, evaporation, and inflow indicates that the upper lake-level exceedance levels from the water mass-balance model are particularly sensitive to parameter uncertainty. The sensitivity in the upper exceedance levels was caused almost entirely by uncertainty in the fitted probability distributions of the quarterly inflows. A method was developed for using long-term streamflow data for the Red River of the North at Grand Forks to reduce the variance in the estimated mean. Comparison of the annual lake-volume model and the water mass-balance model indicates the upper exceedance levels of the water mass-balance model increase much more rapidly than those of the annual lake-volume model. As an example, for simulation year 5, the 99-percent exceedance for the lake level is 1,417.6 feet above sea level for the annual lake-volume model and 1,423.2 feet above sea level for the water mass-balance model. The rapid increase is caused largely by the record precipitation and inflow in the summer and fall of 1993. Because the water mass-balance model produces lake-level traces that closely match the hydrology of Devils Lake, the water mass-balance model is superior to the annual lake-volume model for computing exceedance levels for the 50-year planning horizon.

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